AUG 2 6 1981

982-D-23 TD 8.22: C 82

NHTSA Technical Report
DOT-HS-805 888

COMPLETED
49

ORIGINAL

A COST/BENEFIT STUDY OF A POTENTIAL AUTOMOTIVE SAFETY PROGRAM ON DAYLIGHT RUNNING LIGHTS

April 1981

Prepared by

U.S. DEPARTMENT OF TRANSPORTATION
National Highway Traffic Safety Administration
Office of Vehicle Safety Standards
Washington, D.C. 20590

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no liability for its contents or use thereof.

BEST DOCUMENT AVAILABLE

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT-HS-805-888		

4. Title and Subtitle	5. Report Date
A Cost/Benefit Study of a Potential Automotive Safety Program on Daylight Running Lights	April 1981
	6. Performing Organization Code
	8. Performing Organization Report No.
7. Author(s)	
Kaehn, Charles H.	
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Crash Avoidance Division Office of Vehicle Safety Standards, Rulemaking NHTSA/DOT	11. Contract or Grant No.
	13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address	
NHTSA/DOT Washington, D.C. 20590	Final March 1980-April 1981
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

This report is concerned with determining and evaluating the costs and benefits of a potential automotive safety program on daylight running lights. The term, daylight running lights (DRL), means any of a variety of lighting systems on motor vehicles that are activated to improve vehicular conspicuity during daylight hours. The purpose is to make the vehicle more noticeable to other roadway users and hopefully, thereby, reduce highway accidents. Although this study concludes that the costs are greater than anticipated, the research also shows that potential safety benefits are large enough to warrent further investigation into DRL as a promising accident reduction countermeasure. This report also incorporates a decision analysis technique that provides management with a useful analytical tool to evaluate Agency alternatives without placing a predetermined dollar value on human life for injury.

17. Key Words	18. Distribution Statement
Driver Visibility; Automotive Lights; Running Lights; Daylight Conspicuity; Crash Avoidance; Cost/Benefit Study; Automotive Safety.	Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	46	

Form DOT F 1700.7 (8-72) Reproduc[illegible] authorized

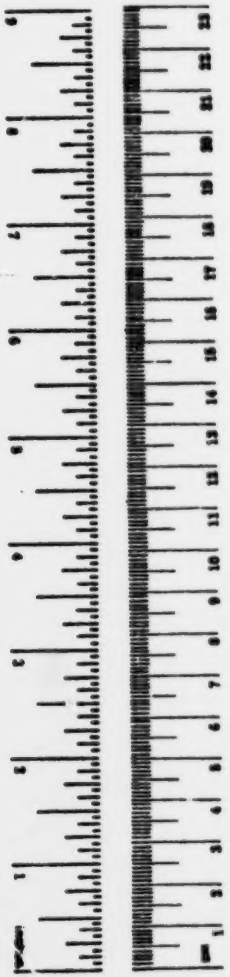
BEST DOCUMENT AVAILABLE

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

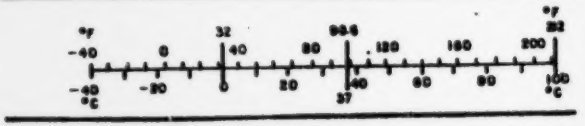
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	S
		LENGTH		
mm	millimeters	0.04	inches	
cm	centimeters	0.4	inches	
m	meters	3.3	feet	
m	meters	1.1	yards	
km	kilometers	0.6	miles	
		AREA		
cm^2	square centimeters	0.16	square inches	
m^2	square meters	1.2	square yards	
km^2	square kilometers	0.4	square miles	
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	
kg	kilograms	2.2	pounds	
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	
l	liters	2.1	pints	
l	liters	1.06	quarts	
l	liters	0.26	gallons	
m^3	cubic meters	35	cubic feet	
m^3	cubic meters	1.3	cubic yards	
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	



BEST DOCUMENT AVAILABLE

TABLE OF CONTENTS

	Page Number
Introduction	1
Background	2
Early Research	3
Later Research	5
Unanswered Questions	8
Scoping the Problem	9
DRL System	10
Cost Factors	11
Benefits Analysis	14
Relevant Accidents	15
Assumptions	16
Estimating Procedure	17
Estimated Accidents	19
Management Consideration	20
Decision Analysis Technique	22
Decision Analysis Model	24
Model Data	26
Interpretation of Graphs	28
Conclusions	29
Recommendations	30
Notes	31
Appendix A	33

BEST DOCUMENT AVAILABLE

"A Cost/Benefit Study Of A Potential Automotive Safety Program On Daylight Running Lights"

by: Charles H. Kaehn

Head, Vehicle Visibility Group

Office of Vehicle Safety Standards

National Highway Traffic Safety Administration

"From either an individual's or society's point of view, presumably there are safety precautions (or risks) worth taking depending upon costs (or benefits), the probabilities involved, wealth, risk aversion, and other factors."(1)

Introduction

Public administrators are under increasing pressure to evaluate more fully promising new safety, environmental, health, and other social programs to determine if they are reasonable, practical, and economical. Recently, for example, the Federal Government has shown a greater interest in determining the effect of its regulations upon the domestic automotive manufacturers in view of that industry's current financial problems.

This report is concerned with determining and evaluating the costs and benefits of a potential automotive safety program on daylight running lights. The term, daylight running lights (DRL), means any of a variety of lighting systems on motor vehicles that are activated to improve vehicular conspicuity during daylight hours. The purpose is to make the vehicle more noticeable to other roadway users and hopefully, thereby, reduce highway accidents.

BEST DOCUMENT AVAILABLE

The author initiated this research to complete credit requirements for the Key Executive Program of The American University. His supervisors at work had suggested conducting a cost and benefit study of DRL since this was a topic of interest to his Agency, the National Highway Traffic Safety Administration (NHTSA). During the course of this investigation, the author served as project manager, initiating two research contracts and enlisting aid from several staff members at the Agency.

Although this study concludes that the costs are greater than anticipated, the research also shows that the potential safety benefits are large enough to warrant further investigation into DRL as a promising accident reduction countermeasure. This report also incorporates a decision analysis technique that provides management with a useful analytical tool to evaluate Agency alternatives without placing a predetermined dollar value on human life or injury.

Background

The number of accidents, injuries, and fatalities resulting from motor vehicle collisions are staggering! Over half of the accidental deaths in this country occur on the Nation's highways. During 1979, there were 51,900 fatalities and 4,740,000 injuries as a result of 18.1 million motor vehicle accidents. According to the National Safety Council, this accident cost amounted to 35.8 billion dollars.(2)

Public concern for this nationwide safety problem caused the Congress to pass the National Traffic and Motor Vehicle Safety Act in 1966. That Act, Public

BEST DOCUMENT AVAILABLE

Law 89-563, stated that its purpose was to "provide for a coordinated national safety program and establishment of safety standards for motor vehicles in interstate commerce to reduce accidents involving motor vehicles and to reduce the deaths and injuries occuring in such accidents."(3)

Since that law was passed, the NHTSA, as the agency responsible for automotive safety regulations, has promulgated over 50 Federal motor vehicle safety standards (FMVSS) which apply to, or effect, new vehicles and certain items of automotive replacement equipment. The States retain jurisdiction over the vehicles once they are operating on highways; therefore, the Federal regulations are applicable only to new vehicles.

One of the first standards issued covered the automotive lights, signals, and reflectors. The goals of this regulation were to assure that drivers had adequate roadway illumination at night, to provide for vehicular identification in the dark, and to provide for intervehicular communication during all hours of operation. This rule did not, however, address the problem of improving vehicular daytime conspicuity to reduce collisions between dawn and dusk driving conditions. The NHTSA became interested in the possibilities of some sort of a running lights program to improve conspicuity as a result of several studies conducted in this country, Canada, and Europe.

Early Research

During the 1960's various field tests were made to determine if some sort of DRL program might not be an effective crash avoidance countermeasure. One of the first was an on-the-road experiment conducted by the Greyhound Corporation

BEST DOCUMENT AVAILABLE

involving approximately 5,000 buses. They concluded that Greyhound had a 10 percent reduction in daytime accidents when comparing collisions before and after a headlights on program. Unfortunately, the company did not publish a report of their study, so it is not possible to evaluate the experimental methodology used or how experimental variables were controlled.

Dr. Merrill Allen reported a 38.7 percent reduction in accidents when vehicles used an extra 21 candlepower lamp in the center of the grill as a daytime running light. His study compared a group of vehicles driven 18 million miles to a similar group without the light. However, Allen concludes that there "is no real evidence from this study which would show how much of this improvement is due to an increase in vehicle visibility and how much is due to nonvisual factors incidental to the use of running lights, such as an increased safety consciousness of the drivers."(4)

The New York Port Authority conducted a test involving some 200 automobiles that were modified so that the vehicles' parking lights and taillights were turned on automatically by the ignition switch. Another 400 nonmodified vehicles were used as a control group. Comparing accident records with that of the unmodified control group, the modified group had an 18 percent lower accident rate. Apparently a large part of that accident reduction came from a significant drop in rear-end accidents.(5)

In Chicago the Checker Cab Company compared their vehicle collision rates against those of another cab company during a year-long test when Checker Cab

BEST DOCUMENT AVAILABLE

used headlights as daytime running lights. The study involved approximately 6,000 drivers traveling 120 million miles. The company reported a 7.2 percent overall reduction in accidents.(6)

While methodological problems of control and exposure rates are apparently a problem in some of these early studies, nevertheless it was encouraging that all of these field tests reported that the various types of DRL systems were an effective crash avoidance countermeasure. However, no quantitative safety benefit conclusions could be drawn from this data, since different running lights approaches were evaluated on fleets that had greatly different operational modes. Moreover, none of these four studies provided information on the initial and operational costs of the DRL systems tested.

Later Research

The problem, then, was to obtain more meaningful data. A larger and better documented DRL study was conducted in northern Europe. In Finland, a DRL law went into effect in November 1972. The regulation required the use of low-beam headlights during winter months when driving outside of built-up areas. The study analyzed all relevant accidents from 1968 to 1974 both before and after the regulation went into effect.

An important aspect of this research was that all types of vehicles were included in the study, not just taxi cabs or buses as in some of the previous field tests. Moreover, the study included all types of drivers, not just professional drivers as were used in the above mentioned fleet experiments.

BEST DOCUMENT AVAILABLE

Anderson, Nilson, and Salusjarvi made a thorough statistical analysis of the effects of the law. The analysis was based upon the assumption that if the increased usage of warning lights had no effect, the changes in accident rates before and after the law should have been the same for daylight and darkness accidents. The authors concluded that there was a 21 percent reduction in daylight multiple vehicle accidents attributable to the DRL law. They also found that there was: (1) a 28 percent reduction in multiple accidents in "meeting directions," such as would happen on a 2-lane road; (2) a 24 percent reduction daylight pedestrian accidents; and (3) a 17 percent reduction in "crossing direction" accidents, such as at intersections.(7)

The DRL requirements in Sweden were different than in Finland. The Swedish law was general--it covered all vehicles, in all locations, throughout the year. However, the law did not become effective until October 1, 1977, and it allowed the usage of either low beams or other "corresponding" forward lights. Preliminary data did show that the DRL law was effective and was more beneficial in rural areas than in urban areas.

In his recent presentation at the 1981 Society of Automotive Engineers Congress, Rumar concluded that this DRL law in Sweden reduced daytime collisions from 5 to 15 percent, although he stated that at present the data cannot be considered statistically significant. Perhaps more important was the interesting information he reviewed on installation and operational costs.(8)

Rumar analyzed three different equipment alternatives that would meet the Swedish DRL law. He calculated that automatic actuation of the low beam

BEST DOCUMENT AVAILABLE

headlamp on new cars would cost about $3, while a reduced voltage low beam system would cost $8, and a special running lights system would cost $25. Rumar also calculated the yearly operational cost based upon an estimated increased lamp burning time of 150 hours per year. He concludes that this extra fuel and bulb replacement cost would be from $5 to $14 a year for the three alternative systems, depending upon whether the system used incandescent lamps or halogen lamps. In his analysis, Rumar states that the extra fuel consumption amounted to about a 1 percent increase due to the extra electrical load.

Attwood reported on a smaller DRL study in Canada started in 1975. Data was collected on 350 nonmilitary vehicles for a 21 month period from six Canadian Forces Bases across Canada. Vehicles in each base were paired by year, make, model, color, and employment. One vehicle in each pair was modified so that its low-beam headlights and all other running lights came on whenever the engine was operating.

Attwood found a 20 percent reduction in relevant accidents, but he noted that the data cannot be considered statistically significant because there were too few collisions. After analyzing property damage costs, he concluded that the accidents involving modified vehicles were much less serious than those that were not modified. He estimated that gasoline consumption would be increased between one-half and 1 percent when low-beam headlights are used in the daytime. Attwood also concluded that other operating costs would be about $47 greater over 100,000 vehicle miles, and he found that the largest element of that cost was due to more frequent headlamp replacement.(9)

BEST DOCUMENT AVAILABLE

Studying the results from these three recent on-the-road tests, the effectiveness of a DRL system seems clearly defendable even though the results from two of the three studies were not statistically significant. Considered together with the four fleet tests during the 1960's, some form of a DRL system should be a useful accident avoidance countermeasure.

Unanswered Questions

The major unanswered question is: "How effective would a suitable DRL system be in this country?" Obviously, the roadway systems and driving environments in Sweden and Finland are greatly different than that in the United States. Even the results from Canada are not necessarily transferable to the lower latitudes where winter is less severe and dusk and dawn conditions are much different.

Moreover, these studies did not answer the question: "What alternative running light method would be the most practical and effective?" The seven field studies used three major DRL approaches. Some used just the low-beam headlamp or an additional forward facing lamp. Others used the low-beam light together with the rearward running lights. One used the front and rear parking lights.

Each approach poses different manufacturing cost considerations as well as different maintenance and fuel cost considerations. Also, the three approaches may not have the same value as an accident advoidance countermeasure. Obviously, the conspicuity effectiveness of an approach which uses both forward and rearward lighting should be different than a DRL system which used only forward facing lights.

BEST DOCUMENT AVAILABLE

Scoping the Problem

At this point in the investigation it was necessary to scope the problem prior to making any further analysis of a potential DRL program. Before any additional study could be made of costs and benefits, the DRL approaches had to be narrowed down. There was not enough time, manpower, nor monies available to investigate simultaneously all three running light approaches reported in the literature.

In view of this, the author decided that this research would analyze only a forward running light system. Any additional benefits or costs from rear lighting (or possible negative effects, such as reducing brake light effectiveness) could be considered at a later time if the results of this study showed a forward DRL approach was cost effective.

However, the author was not prepared to decide what specific type of forward lighting system would be the most practical. Instead, an automotive engineering consulting firm was hired to determine which forward lighting system would be most practical when considering production feasibility, consumer cost, and leadtime requirements.

The contractor was first to investigate several equipment techniques, including the addition of a single center light, roof mounted lights, addition of a bright filament to the front turn signal lights, a reduction in brightness of the low-beam headlights, and automotive low-beams. Once the contractor determined the most feasible system, then he was to analyze the initial and operating costs for each major vehicle category--passenger cars, light trucks and multipurpose vehicles, medium and heavy trucks, and buses.

BEST DOCUMENT AVAILABLE

DRL System

The contractor, the ITT Research Insitute, based their analysis principally upon the potential effects a DRL system would have on future passenger cars. Any NHTSA rulemaking initiated soon would take at least 2 or 3 years before it would affect production models; therefore, the analyses had to consider the projections of downsizing automobiles, the emphasis on fuel economy, and the trend towards more sophisticated electronic controls and added electrical accessories. Moreover, the contractor noted that approximately 75 percent of all registered vehicles are passenger cars; thus, he thought it reasonable to place primary emphasis on the probable design problems and cost considerations for this class of motor vehicles.

After studying the various options, the contractor concluded that automatic actuation of the low beam headlamps would be the most practical approach. They stated that a single center light, although attractive from a lower electrical consumption standpoint, would not have the safety benefit of a two lamp system. Moreover, they said that installation of a light in the middle of the grill would not be a simple design change. Additional support structure would be required, space problems were a complicating factor, and interference with the air flow for the engine cooling system was a third design problem.

Roof mounted lights were also rejected because of several design problems, including the possibility of increasing aerodynamic drag and fuel consumption. However, the contractor did conclude that these high mounted lights might be more visible, especially when compared to the parking lights which were considered too low. The visibility distance of the parking lights could be

BEST DOCUMENT AVAILABLE

improved by adding a bright filament to the front turn signal, but then the total electrical consumption is only slightly less than for headlights. Moreover, the contractors concluded that the light projection or distribution of the turn signals was not as satisfactory as that for low beam headlamps, and they also felt the addition of a brighter filament would interfere with the turn signal and hazard warning signal functions.

As a result, the contractor conducted his cost analysis on a low beam DRL system. While a reduction in brightness of the low beam headlights was considered electrically possible, they assumed that such an approach would result in no real reduction in electrical consumption. Such systems would use a small resistance in the circuit that would convert the wattage to heat but would not reduce the total energy consumption.

Cost Factors

Two cost factors were analyzed. First, the initial or additional purchasing cost. This would be a single time investment cost for the consumer. Second, the yearly operational costs, which consists of additional maintenance and fuel costs. These costs continue throughout the life of the vehicle.

The contractor found that most future car models would not have adequate electrical charging systems to handle the increased power consumption of a daylight low beam system. According to his findings, new car designs are aimed at reducing weight to reduce fuel costs; therefore, the electrical charging systems are designed to just meet the expected wattage requirements. These requirements include increased use of air conditioners and rear window

BEST DOCUMENT AVAILABLE

defogging units, but they do not include utilization of the headlamps during the day. At present, only about 20 to 25 percent of the total driving time takes place at night, so a DRL system would increase headlamp usage by four or five times the current usage rate.

This increased utilization would also mean that the headlamps would have to be replaced more often. Since the contractor found that by model year 1984 almost all domestic model cars would use halogen headlamps instead of the older tungsten filament lamps, the replacement costs would also be greater because halogen headlights are more costly.

After considering the capital investment requirements for redesign and retooling costs, the contractor determined that the greater initial cost to the purchaser would be about 39 dollars for passenger cars, 44 dollars for light duty trucks and multipurpose vehicles, and 80 dollars for heavier trucks and buses. The cost data are summarized on Table I. This would amount to an extra consumer cost of about 526 million dollars a year (based upon 1980 dollars). Most of this cost would be for upgrading the electrical charging systems.

Perhaps more startling, however, were the annual maintenance costs of the DRL program. The contractor determined that yearly expenses would be almost 27 dollars a year for passenger cars, light and medium trucks, and multipurpose vehicles, 35 dollars for heavy trucks, and from 10 to 52 dollars for the different bus models. This includes an increased fuel usage of about one-half percent per year. Most of the maintenance cost would be for increased frequency

BEST DOCUMENT AVAILABLE

Table 1

Estimates of Motor Vehicle Costs

	Initial	Annual maintenance and fuel
passenger cars	$39.26	$26.97
light trucks	$44.23	$26.97
heavy trucks	$80.00	$34.61
buses	$80.00	$10.19-$51.87

BEST DOCUMENT AVAILABLE

of headlamp replacement. Both of the initial and operating cost estimates of the ITT Research Institute were much higher than those reported in the Swedish & Canadian studies.

The first year of introduction would cost the public approximately 388 million dollars for maintenance plus the 585 million dollar investment cost for a total of 973 million dollars. Once the entire fleet had a DRL system, the extra yearly maintenance and fuel costs alone would exceed 4.5 billion dollars a year. (10)

Obviously, this cost data appears to make any such DRL program impractical. Nevertheless, it is worth exploring the potential benefits this accident countermeasure might provide, since it is always possible that at some future date advancements in technology might significantly reduce the initial and operating cost estimates.

Benefits Analysis

Once it was decided that this study would limit itself to a forward lighting system, then it was possible to address the unanswered question: "How effective would a suitable DRL system be in this country?" Thus, a benefits analysis was initiated to run concurrently with the cost study.

A research consultant was hired to provide the needed expertise to help the author develop a systematic technique to estimate the potential effectiveness of the DRL program. The consultant, Dr. Charles Harvey from Dickinson College, had recently worked for a year at NHTSA headquarters under the Intergovernmental

BEST DOCUMENT AVAILABLE

Personnel Act. Thus, he was not only well acquainted with previous NHTSA cost and benefit studies, but Dr. Harvey was also familiar with the Agency's Fatal Accident Reporting System (FARS) and its National Crash Servity Study (NCSS). Both of these accident data files were used extensively in the benefits analysis. The Pedestrian Injury Causation Study (PICS) and the USC truck and bus accident files were also used to estimate benefits.

Relevant Accidents

The first job was to determine the relevent accident scenario associated with the DRL program. This required an analysis of the literature and use of expert opinion. Since only two staff members at the NHTSA were sufficiently well acquainted with the literature, these two people served as our experts in defining what a relevant accident scenario would be when low beam headlamps would be used as a daytime running light.

Obviously, a relevant accident would be one that occurred between dawn and dusk, not at night when lights were already turned on. In addition, a study of the Finnish data narrowed down the total relevant accident scenario to three traffic accident situations where the data showed a statistically significant accident reduction effect. These were multiple vehicle accidents in meeting directions, such as head on or side swipe crashes on two lane roads, daytime pedestrian accidents, and multiple vehicle accidents in crossing situations, such as at intersections. While one might hypothesize that other accident situations were relevant, the experts concluded that the research reported in Finland indicated that only these accident situations were effectively reduced by the DRL program.

BEST DOCUMENT AVAILABLE

Assumptions

The next step was to estimate the potential effectiveness of a DRL program in the United States. While the experts would use the results of all of the field studies when making their estimates, it was recognized that heavy emphasis would be placed on the Finnish data. After much discussion and additional review of the research reports, the experts agreed that the following four assumptions would guide their subsequent estimates of accident reduction effectiveness:

1. That in all relevant accidents the percentage reduction in this country would be less than that reported in Finland, Sweden, or Canada because of different roadway and environmental conditions. The experts noted that with longer and more severe winters, the road conditions would be more hazardous and the low light periods of dusk and dawn would be longer.

2. That in all relevant accidents, the percentage reduction during full daylight would be less than during dawn and dusk conditions. The experts concluded that the low beam headlamps would have a greater conspicuity value when the ambient light conditions were lower than in bright sunlight.

3. That in all relevant accidents, the percentage reduction for larger vehicles would be less than that for smaller vehicles. The experts recognized that a big vehicle, such as truck tractor trailer combination, was already more noticeable than something like a subcompact car.

BEST DOCUMENT AVAILABLE

4. That in all relevant accidents, the percentage reduction would be less in urban areas than in rural areas. The experts noted that the preliminary accident data from Sweden showed a greater effectiveness in the rural areas.

Estimating Procedure

Once having agreed upon these four assumptions, the experts were ready to estimate the potential effectiveness of a DRL system on each individual relevant accident situation. The total relevant accident scenario was broken into the three major accident situations, or populations, noted previously when the experts reviewed the data from Finland. Population I covered intersection type accidents. Population II covered pedestrian type accidents, and population III covered two lane road type accidents.

These populations were further subdivided to incorporate the estimating assumptions the experts agreed upon. Each population, therefore, was broken down into a number of subpopulations, or cells, to define such different factors as dawn and dusk vs. full daylight driving conditions and rural roadway vs. urban roadway environments.

Figure 1 shows one of the three evaluation forms used by the experts. Note that this particular form was for the two lane road type of accident. The form has a total of 16 boxes, or cells, that the evaluators used during the estimation process. Altogether there were 64 cells used to cover the three different

BEST DOCUMENT AVAILABLE

Figure 1

Estimates of Fatality Reduction

Population III—Two-lane road type accidents

Dusk & Dawn

	car	light truck	heavy truck	bus
Rural				
Urban				

Daylight

	car	light truck	heavy truck	bus
Rural				
Urban				

BEST DOCUMENT AVAILABLE

populations, the two light conditions, the rural and urban roadway conditions, and the four different vehicle classifications. The 64 cells included additional subclassifications which were needed so that data from the FARS and NCSS computer files could be used.

Estimated Accidents

Using the FARS computer file, we determined that there would be a total of 9134 relevant fatalities per year that the DRL program would hope to reduce by some amount. Only 7.65 percent of these fatalities occur during dawn and dusk lighting conditions; therefore, the safety problem is predominately one during full daylight. Using the NCSS file, we projected that there would also be a total of 1,077,169 relevant serious injuries per year that a running lights system could be expected to alleviate in some measure.

This then, is the total accident scenario that a DRL countermeasure would expect to offset. Note that property damage accidents and less serious injuries were not included. We felt that we could not make statistically sound projections for these accident situations with the computer data readily available at NHTSA headquarters. The reader will realize, then, that the accident picture is underrepresented. This is a factor to consider when comparing costs and benefits.

Using the percentage reduction data from one expert, we determined that the DRL program should reduce the above total relevant fatalities and serious injuries by 365 less deaths and 43,044 less serious injuries per year. The second expert had estimates resulting in 189 less fatalities and 22,289 less serious injuries annually.

BEST DOCUMENT AVAILABLE

Obviously, there was almost a two-to-one difference in the estimates between the two experts. This reflects the uncertainty involved in trying to project the effectiveness of a new crash avoidance countermeasure. The estimating problem was compounded by using accident data not thought to be representative of the driving situation on our nation's highways.

The Finnish study had reported a 21 percent reduction in daylight multiple vehicle accidents attributable to running lights. In this benefits analysis, the one expert had estimated an average of a 4.0 percent reduction in total relevant accidents. The other estimated a 2.1 percent reduction. In other words, the experts estimated that a DRL program in this country would be from approximately one-fifth to one-tenth as effective as that reported in Finland.

Management Considerations

The management problems facing the agency in this study are not unlike those facing other public administrators. While there are some cost and benefit data, there are still a lot of unknowns that make the decision making process difficult.

However, at this point in the report it is useful to compare the estimated benefit costs with the estimated vehicular costs. In 1975 the NHTSA published a report entitled "Societal Costs of Motor Vehicle Accidents." This report estimated that the total societal cost of a motor vehicle fatalilty was $287,175 (in 1975 dollars). Injury costs were based on a six step injury severity index ranging from a low of 2190 dollars to a high of 287,175 dollars.(11)

BEST DOCUMENT AVAILABLE

Since this DRL study used only serious injuries, it appears that step 4 of the six step scale appears to best fit the injury situation under consideration. Step 4 was defined as a severe injury where survival is probable. The estimated societal cost was 86,955 dollars.

Adjusting 1975 dollars to 1980 dollars, the revised fatality cost estimate is now approximately 430 thousand dollars and the revised severe injury cost is now 130 thousand dollars. Multiplying these costs by the high and low benefit estimates, the annual dollar value of lives saved would range from $81 to $157 million. The injury reduction would be worth from 2.9 to 5.6 billion dollars yearly. Therefore, the total safety benefits in 1980 dollars would range from about $3.0 to $5.8 billion each year, not counting property damage and less severe injury cost savings.

These data can be compared to the ITT Research Institute vehicular cost estimates. The annual investment cost was 585 million dollars, and the yearly nationwide fleet operational costs were about 4.5 billion dollars. Adding these two items, the cost side was estimated to be about 5.1 billion dollars a year. The societal benefits, then, could be slightly greater or less than the vehicular costs.

Lets review the major management considerations at this time. For one thing, there is a great deal of uncertainty in the data. On the benefits side, there is a large difference between the estimates of the two experts. This problem becomes confounded when one multiplies these data by societal cost data that in itself are open to question. Moreover, there is much uncertainty in trying to

BEST DOCUMENT AVAILABLE

translate results from special fleet studies or foreign DRL programs to the American driving scene. The same types of problems arise when considering the investment and operating cost data.

On the other hand, the total impact of these cost and benefit estimates are staggering. If these estimates are anywhere near correct, we're talking of an existing conspicuity accident situation that is costing society billions of dollars a year. Unfortunately, the countermeasure also appears to cost about the same amount. However, the magnitude of the problem demands that a more careful analysis be made of the DRL program.

Decision Analysis Technique

One of the most important aspects of having Dr. Harvey as a consultant was his ability to provide a decision analysis model that would aid management in comparing alternative management decisions. Although we were not able at this stage of our DRL study to develop new or additional safety benefit or vehicular cost data, Dr. Harvey worked out an analytical technique that made it possible to use various levels of benefits and costs and see how these changes would affect the decision making process.(12)

Moreover, the author felt that top management should be provided with analytical information that enabled them to make comparisons of alternative regulatory actions without using a predetermined dollar value of human life or injury. In order to do this, the decision analysis model incorporated two tradeoff factors, (c/f) and (c/i). The tradeoff factor (c/f) is defined as the cost that society

BEST DOCUMENT AVAILABLE

would just be willing to pay per decrease of one highway fatality. The (c/i) factor is the cost society would just be willing to pay per decrease of one serious injury from a motor vehicle accident.

What, then, are the management alternatives the NHTSA should consider when evaluating this DRL program? The author decided that there were three principle alternatives, as follows:

Alternative (A) would be for management to decide to not issue a DRL regulation within the near future and to decide to not engage in any additional field studies or research beyond this research report. This alternative would mean that management considered the safety benefits too small and/or the vehicular costs too great to warrent further NHTSA consideration at this time.

Alternative (B) would be for management to decide to issue a DRL regulation for all new vehicles as soon as possible. Such regulatory action would take at least two years before it would apply to new vehicles. This alternative would mean that management considered the safety benefits large enough and/or the vehicular costs small enough to warrent regulatory action on the basis of the findings in this report.

Alternative (C) would be for management to decide to defer making a final decision until after additional NHTSA research and field

BEST DOCUMENT AVAILABLE

testing. This alternative would postpone the decision for at least 5 years, since it would take that long to fund and conduct additional evaluation studies. The cost of this additional research and development was estimated at approximately 500 thousand dollars.

Obviously, alternative (C) must involve a consideration of the consequences of deferring the decision making process an additional 5 years. The advantage of having additional research data and field testing experience on a DRL program must be weighed against the disadvantages of this delay should the DRL approach prove to be effective and additional lives are lost and injuries occur during this research period.

Decision Analysis Model

In the decision analysis model, alternatives (A), (B), and (C) were compared by regarding the costs and benefits associated with alternative (A) as base amounts and determining the extra costs and extra safety associated with (B) and (C). The cost and benefit inputs are based upon those vehicular cost data from the ITT Research Institute contract and the safety benefit data from the analytical technique that used the 64 estimating cells.

In the model, future costs are discounted by 12 percent per year. This was particularly important when considering alternative (C) which had a 5 year delay period. Since the safety impact can be translated into monetary amounts by the tradeoff factors (c/f) and (c/i), future safety benefits were also discounted by

BEST DOCUMENT AVAILABLE

12 percent. Thus, when comparing the three alternatives, these extra costs and safety are reduced to a single present value amount by means of the tradeoffs (c/f), (c/i), and the discount factor. This is shown as follows:

PV (A) = the present value of alternative (A);

PV (B) = the present value of alternative (B); and

PV (C) = the present value of alternative (C).

Remember that alternative (A) meant that management would decide not to issue a regulation on DRL. Therefore, PV (A) = 0, since there are no present vehicle costs and no present safety benefits associated with (A). The decision analysis model, then, compares the extra costs and extra safety benefits associated with (B) and (C) with alternative (A).

When developing the model, it was necessary to expand upon the benefit analysis previously made by the two experts. In that analysis, the experts had made only a single percentage reduction estimate for each of the 64 relevent accident cells. Now, however, it was necessary for each expert to not only assess the percentage reductions in each cell, but also to assess his uncertainity as to these percentage reductions. Clearly the degree of uncertainity should influence the desirability of alternative (C).

This uncertainity was quantified as follows. First, the original estimate was considered the median value, M, for the percentage reduction in a cell. Then the two experts had to assess a lower quantile, L, and an upper quantile, U, for each cell. The interpretation of these assessed values meant that the expert

BEST DOCUMENT AVAILABLE

believed that the true percentage reduction was equally likely to fall into each of the four intervals: O-L; L-M; M-U; and U-100. In this analytical technique, the closer L and U were to M, the more certain the expert was that his first estimate, M, would be the true percentage reduction.

For each cell, the three assessed values, L, M, and U were used to calculate a normal distribution for the percentage reduction in the cell. These distributions were related to each other by assuming that any two differ by a fixed linear transformation. There were three analyses used. First, an analysis using the probability distributions derived from one experts assessment of the percentage reductions. Second, a similar analysis using the other expert's assessments, and third an analysis using probability distributions that assign to any interval of percentages a probability equal to the average of the probabilities assigned by the previous two probability distributions.

In addition, the model incorporated projections of the sales, or registrations, of new vehicles in each of the major vehicle categories (i.e., passenger cars, light trucks and multipurpose vehicles, heavy trucks, and buses). The model also used three sets of vehicular costs by using 100, 75, and 50 percent of the cost data projected by the ITT Research Institute.

Model Data

While it is not the purpose of this report to explain in detail the decision analysis model developed by Dr. Harvey, the author trusts that the reader has gained some insight to the analytical techniques used in this phase of the DRL study. The model itself consisted of several complicated mathematical equations

BEST DOCUMENT AVAILABLE

that required the use of a program analyst, a data processing expert, and a computer. The approach was not unlike that used by private business when a corporation needs to know the present value of taking several alternative actions when estimating, or projecting, possible production costs and sales (or benefits) of a new product line.

The decision analysis model produced plots, or graphs, which show the comparisons of alternative (A) with (B), of (B) with (C), and of (A) and (C). For each of these alternative comparisons, there are 3 cost level projections and 3 benefit level projections. Thus, there are a total of 27 graphs resulting from the multiple of 3 alternatives, times 3 cost levels, times 3 benefit levels. These plots are shown in Attachment A.

Note that on each plot, the (c/f) values (i.e., the cost per fatality) are shown as the horizontal line, or abscissa, on the graph. The (c/f) values are shown on the different graphs using several different scales because of the wide range of (c/f) values under consideration in the model. The (c/i) values (i.e., the cost per serious injury) are shown as the vertical line, or ordinate, on the graph. The (c/i) values are also shown using several vertical scales.

The graphs are used to compare any two of the three alternatives. The slanted line, or hypotenuse, is the boundary on the graph that divides where one alternative is found preferable to another. The graphs identify the areas where (A) is prefered to (B), or where (B) is preferred to (A), and so forth.

BEST DOCUMENT AVAILABLE

Interpretation of Graphs

Management can use these graphs to decide which alternative appears to be the most appropriate for given levels of cost and benefit data. For example, if NHTSA executives thought that a human life had a societal value of about 400 thousand dollars and a severe injury had a value of about 75 thousand dollars, then management could use each of the 27 graphs to determine where these (c/f) and (c/i) coordinates would be positioned on each graph.

Using these assumed societal values, one finds that alternative (A), to not issue a regulation, is preferred to (B), to issue the regulation, in 7 out of the 9 graphs in appendix A where these 2 alternatives are compared. The only two cases where (B) is preferred is where the vehicular costs are estimated to be only half of that originally determined by the ITT Research Institute. In these two graphs, the benefit levels were those using the more optimistic data and those using the average benefit estimates of the two experts.

One can also check the 9 graphs where alternative (B) is compared to (C). When the (c/i) is $75,000 and the (c/f) is $400,000, alternative (C) to conduct further research is preferred to the alternative to issue the regulation in 7 out of 9 graphs. The only two graphs where (B) is preferred is where the benefits were estimated the highest and the cost the lowest and where the average benefits were used with 75 percent cost inputs.

Looking at the 9 graphs comparing alternative (A) to (C), one finds that alternative (C) is preferred in all cases. If one assumes that these societal costs are reasonable, then it is obvious from this data that even under the most

BEST DOCUMENT AVAILABLE

conservative benefit estimates, and the highest cost estimates, the logical decision is for the NHTSA to continue to investigate the possibilities of a DRL program.

Summarizing this particular review of the decision analysis graphs, one finds that alternative (A) is preferred to (B) in all but 2 cases, alternative (C) is preferred to (B) in all but 2 cases, and alternative (C) is preferred to (A) in all cases. Thus one can conclude that there is not much reason to issue a regulation now, nor should the agency drop the DRL program. Of course, different societal values could result in different conclusions.

Conclusions

After reviewing the information presented in this report, the author comes to the following conclusions:

1. In view of the high projected consumer costs, the initial and/or operating expenses would have to be substantially reduced before this DRL program could be viable. This is particularly true at the present time when inflation and fuel economy are serious problems and when the automotive industry is having substantial financial problems.

2. Although the benefit data could not be considered conclusive, there does appear to be adequate justification for concluding that a DRL program could provide substantial safety dividends. Moreover, the data shows that the existing daylight conspicuity problem is more serious than one would have anticipated.

BEST DOCUMENT AVAILABLE

3. The decision analysis model was a useful rational tool to evaluate the three management alternatives without using a predetermined dollar value on human life or injury. The model could be modified as new data is developed, making it useful for future studies. The concepts can be adopted to similar regulatory cost/benefit analyses.

4. The NHTSA should conduct additional research to investigate further the possibilities of a future DRL program.

Recommendations

In view of the previous conclusions, the author recommends that the following action be undertaken by the NHTSA:

1. Conduct a research program to develop an alternative DRL approach that will greatly reduce initial operating costs as well as minimizing the fuel consumption characteristics of such a DRL system. There certainly seems to be every reason to believe that an engineering breakthrough is possible, particularly with the trend towards greater usage of electronic systems in automobiles.

2. Once such a low cost DRL system is developed, conduct on-the-road tests to obtain adequate accident reduction data to determine the practicality and effectiveness of such an accident avoidance countermeasure.

BEST DOCUMENT AVAILABLE

NOTES

1. Bryan C. Conley, "The value of human life in the demand for safety," The American Economic Review, March 1976, Vol. 66 No. 1, pp.45-55.

2. "Accident Facts," 1980 Edition, National Safety Council (Chicago, Illinois). Approximately 43 percent of all fatalities are during the day when a DRL program should improve conspicuity as an accident avoidance countermeasure.

3. Public Law 89-563, 89th Congress, S. 3005, September 9, 1966, the "National Traffic and Motor Vehicle Act of 1966." This law states that all Federal motor vehicle safety standards "shall be practicable, shall meet the need for motor vehicle safety, and shall be stated in objective terms."

4. Merill J. Allen, "Running light questionnaire," American Journal of Optometry, March 1965, Vol. 42 No. 3, pp. 164-167. Allen's data came from a survey of companies known to be using running lights during the day.

5. E.J. Cantilli, "Accident experience with parking lights as running lights," 1970, Highway Research Record No. 332, pp. 1-13. In this study, 66 percent of the vehicles used were passenger cars, 27 percent were light trucks, and the remainder were heavy trucks.

6. Merill J. Allen, "The current status of automobile running lights," Journal of American Optometry Association, 1979, Vol. 50 No. 2, pp. 179-180.

BEST DOCUMENT AVAILABLE

7. K. Anderson, G. Nilsson, and M. Sal··järvi, "The effect of recommended and complusory use of vehicle lighting on road accidents in Finland," National Road and Traffic Research Institute, Sweden, 1976, Report No. 102.

8. Kare Rumar, "Daylight Running Lights in Sweden. Prestudies and Experiences," The Society of Automotive Engineers, SAE paper No. 81 0191, February 1981.

9. Dennis A. Attwood, "The Potential of Daylight Running Lights as a Vehicle Collision Countermeasure," The Society of Automotive Engineers, SAE paper No. 810190, February 1981.

10. D.M. Teaque, et.al, "Implementation Analysis for Daytime Use of Headlights," ITT Research Institute, DOT -HS-805-849, November 1980. This report also gave data on motorcycle and moped costs as well as retrofit costs for all vehicles.

11. "Societal Costs of Motor Vehicle Accidents," 1975, Office of Program Analysis, National Highway Traffic Safety Administration. This report was an update and revision of a societal cost study published in 1972.

12. Dr. Harvey was under NHTSA contract order DTNH22-80-P-02089. The work statement was entitled "Decision Analysis Model for the 'Lights on' Safety Program." The specific details of his decision analysis model are on file at NHTSA headquarters.

BEST DOCUMENT AVAILABLE

APPENDIX A

Appendix A consists of decision analysis model graphs comparing alternatives (A) with (B), (B) with (C), and (A) with (C) for 3 vehicular cost levels (i.e., 100, 75, and 50 percent of ITT Research Industry cost estimates) and with 3 safety benefit levels (i.e., estimates from each expert and the average for the two). For the convenience of the reader, the two experts are identified as "K" and "P" to enable the reader to differentiate between the different estimates.

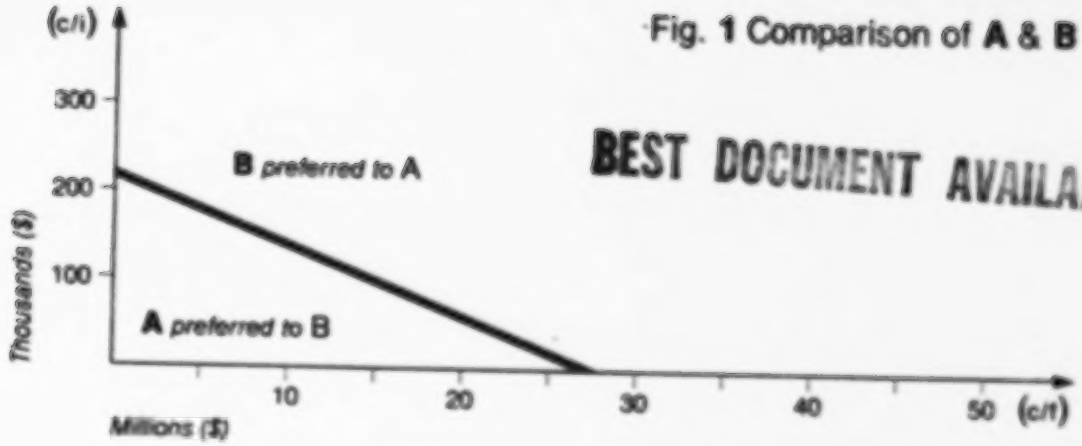


Fig. 1 Comparison of A & B

BEST DOCUMENT AVAILABLE

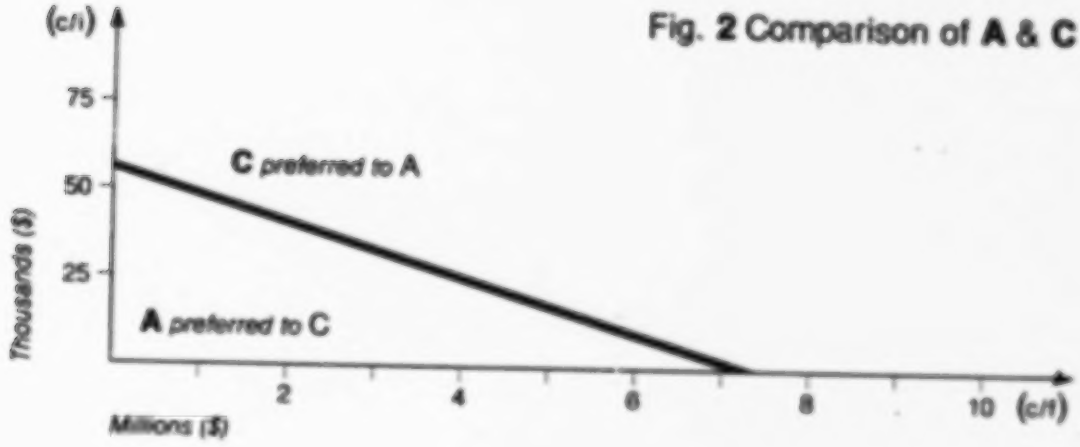


Fig. 2 Comparison of A & C

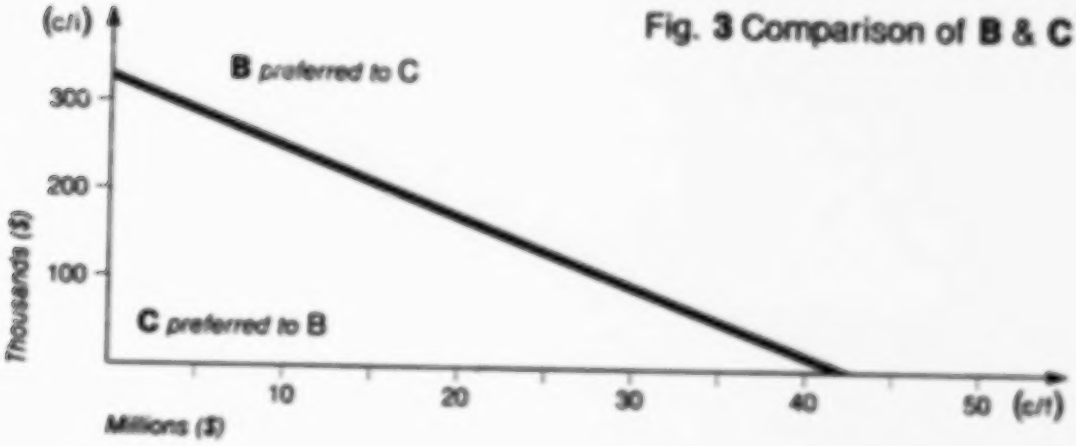


Fig. 3 Comparison of B & C

Figures 1-3 Comparisons of (A), (B), & (C) using 100 percent cost and using safety benefits of expert "K"

BEST DOCUMENT AVAILABLE

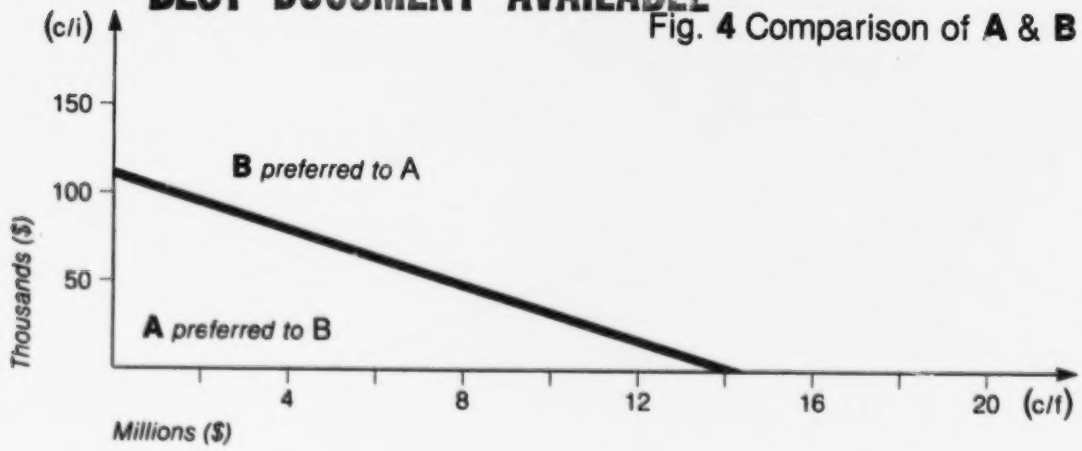


Fig. **4** Comparison of **A** & **B**

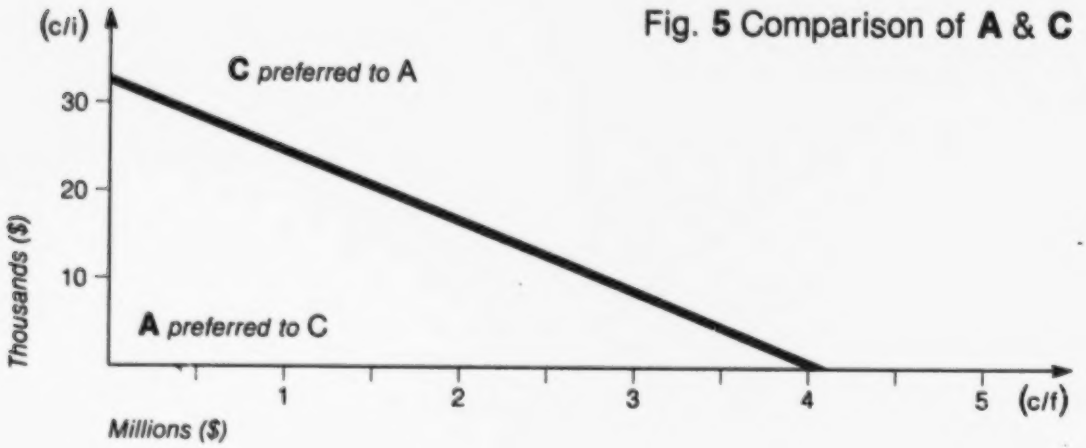


Fig. **5** Comparison of **A** & **C**

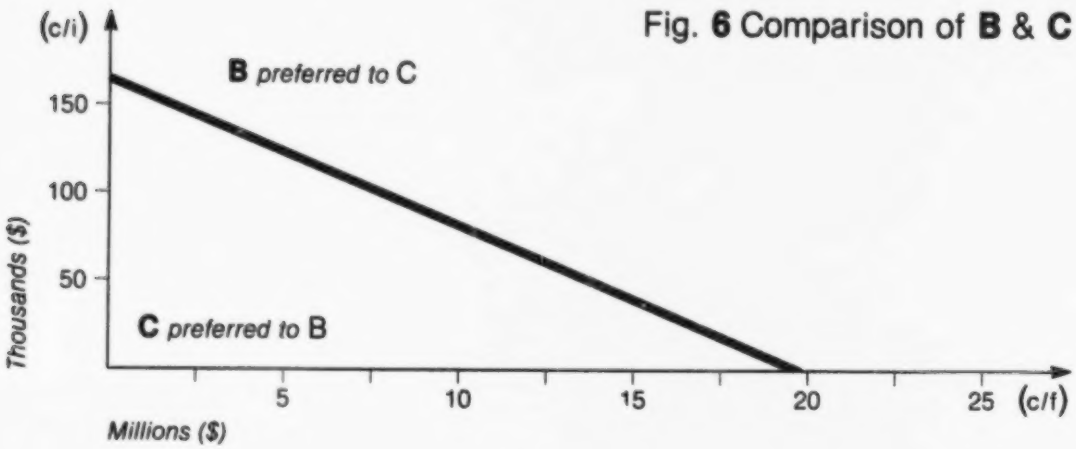


Fig. **6** Comparison of **B** & **C**

Figures 4-6 Comparisons of (A), (B), & (C) using 100 percent cost and using safety benefits of expert "P"

BEST DOCUMENT AVAILABLE

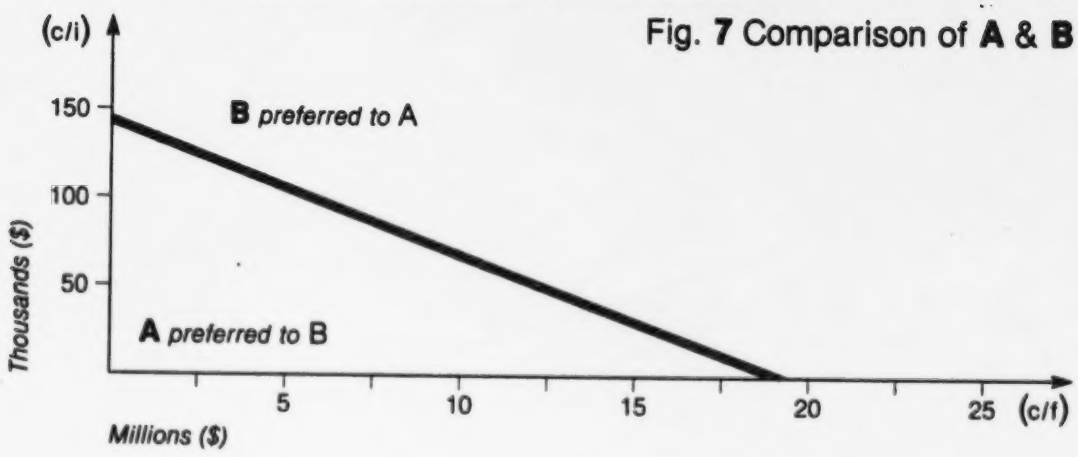


Fig. 7 Comparison of **A** & **B**

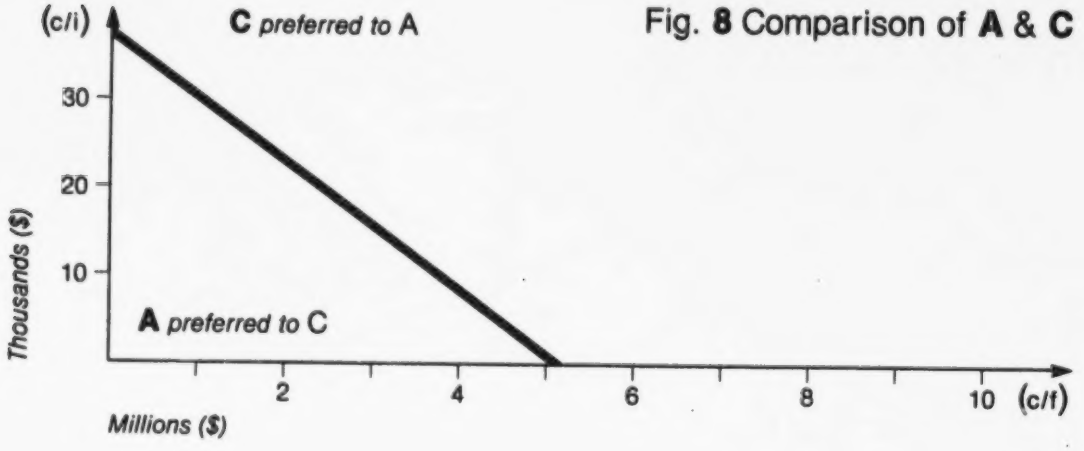


Fig. 8 Comparison of **A** & **C**

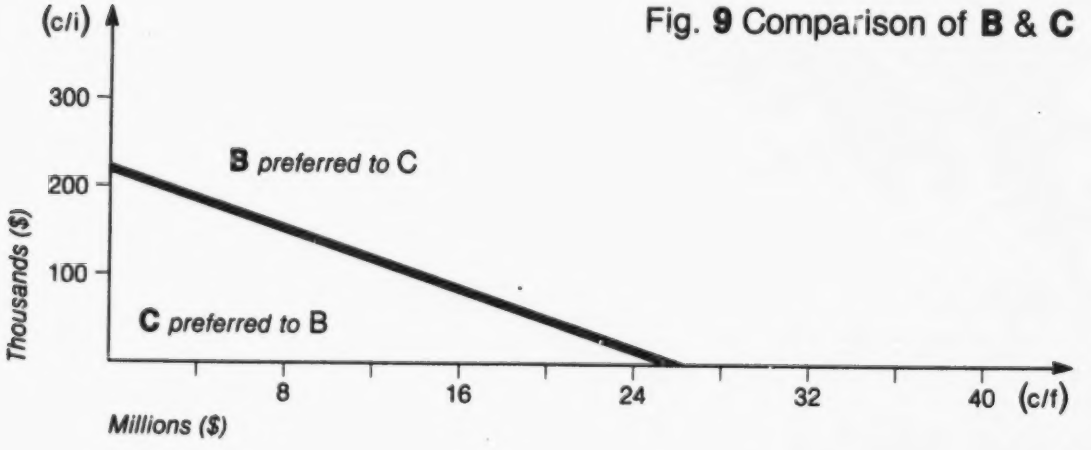


Fig. 9 Comparison of **B** & **C**

Figures 7-9 Comparisons of (A), (B), & (C) using 100 percent cost and using safety benefits of "P" & "K" average

BEST DOCUMENT AVAILABLE

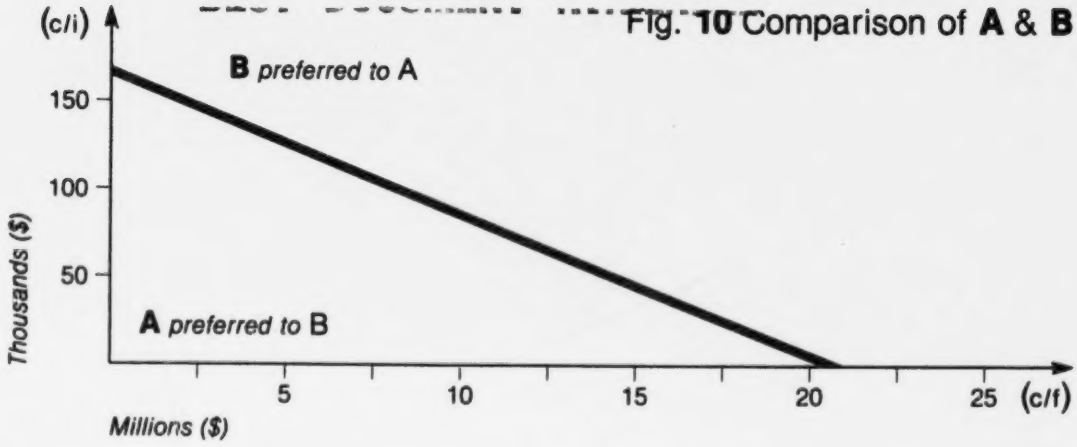


Fig. **10** Comparison of **A** & **B**

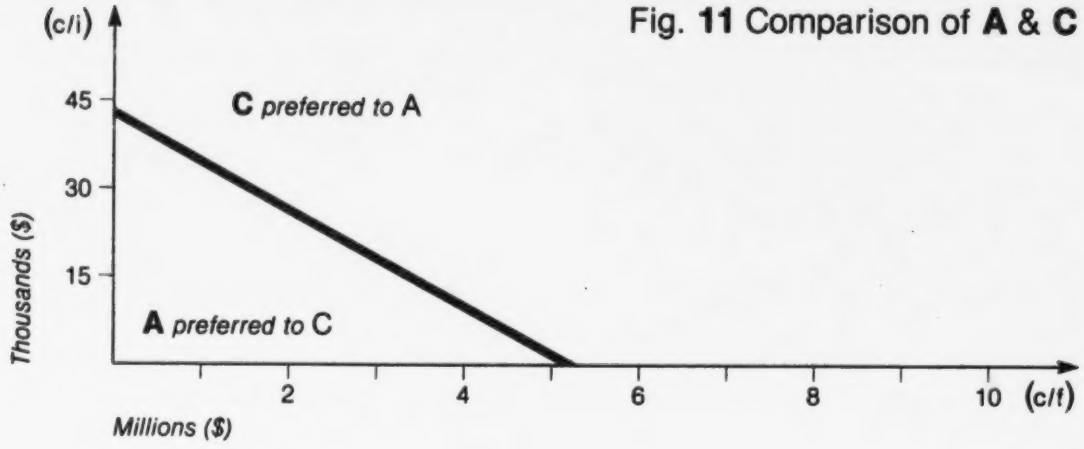


Fig. **11** Comparison of **A** & **C**

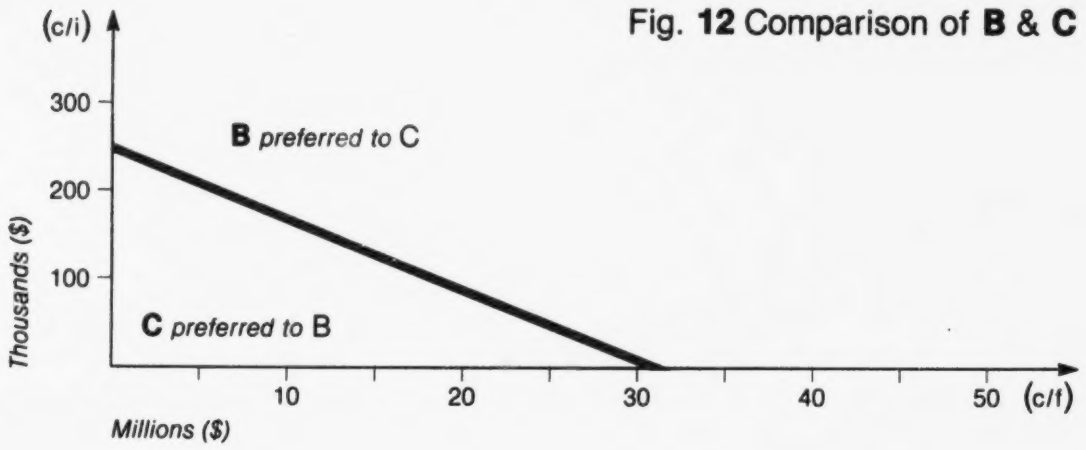


Fig. **12** Comparison of **B** & **C**

Figures 10-12 Comparisons of (A), (B), & (C) using 75 percent cost and using safety benefits of expert "K"

BEST DOCUMENT AVAILABLE

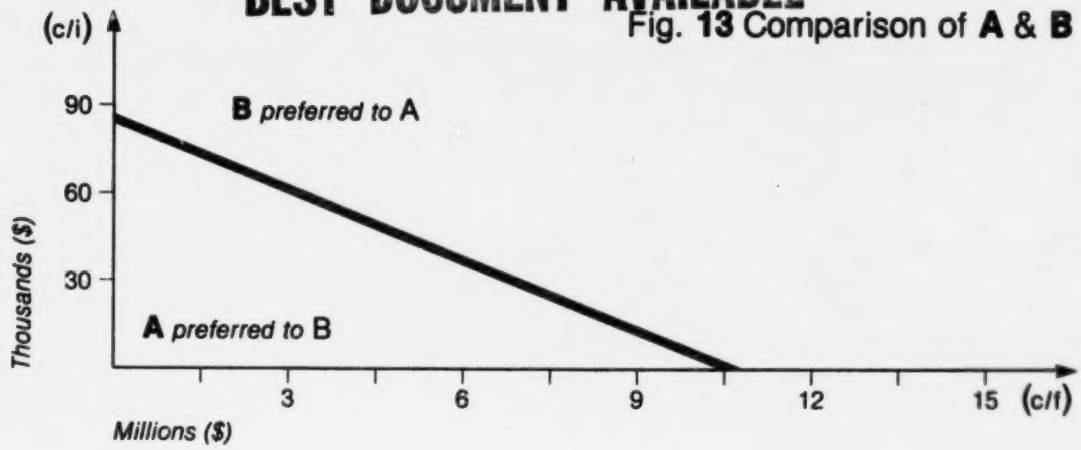


Fig. **13** Comparison of **A** & **B**

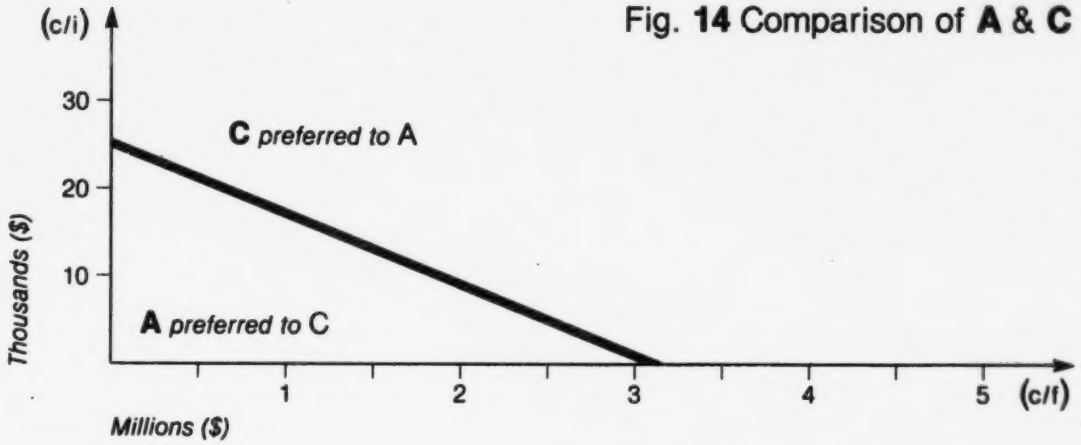


Fig. **14** Comparison of **A** & **C**

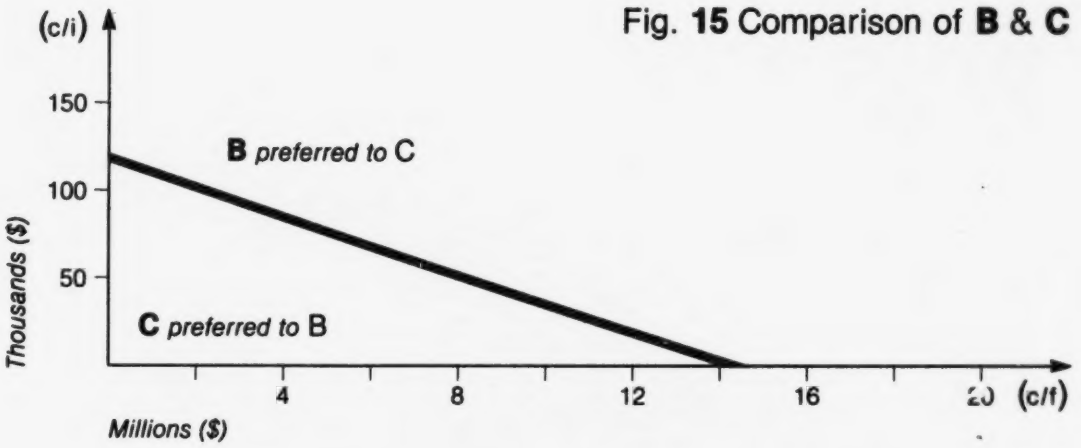


Fig. **15** Comparison of **B** & **C**

Figures 13-15 Comparisons of (A), (B), & (C) using 75 percent cost and using safety benefits of expert "P"

BEST DOCUMENT AVAILABLE

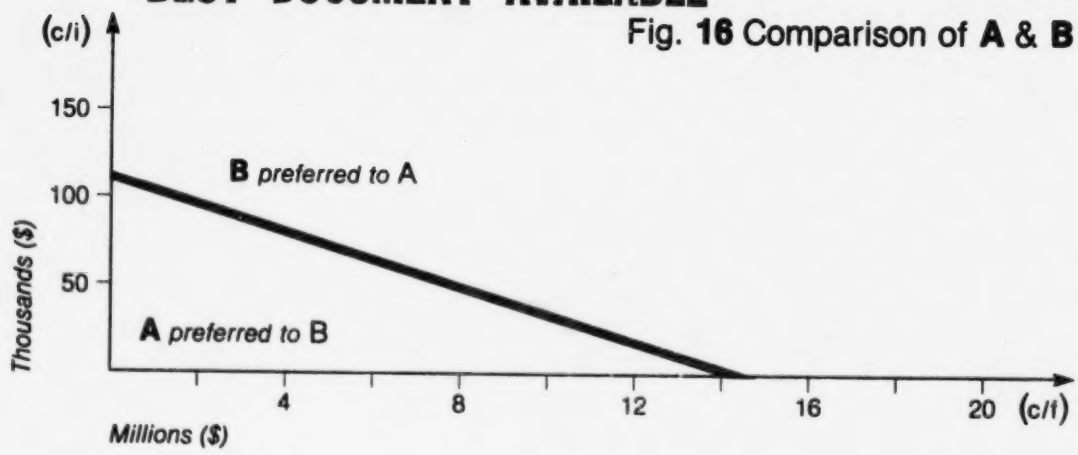


Fig. **16** Comparison of **A** & **B**

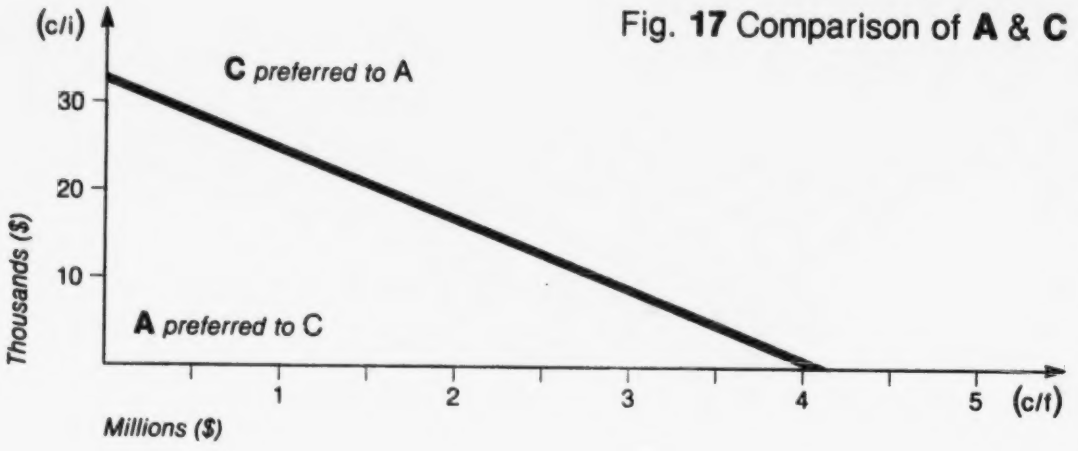


Fig. **17** Comparison of **A** & **C**

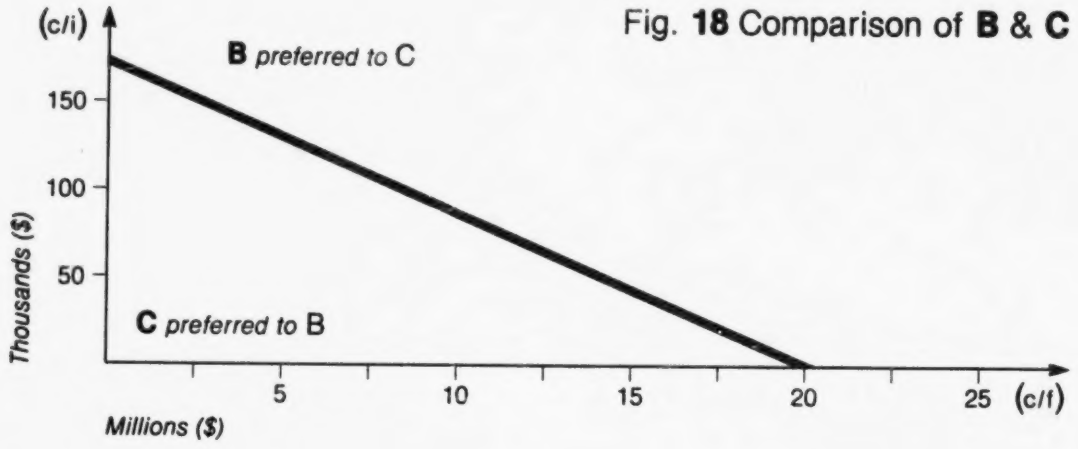


Fig. **18** Comparison of **B** & **C**

Figures 16-18 Comparisons of (A), (B), & (C) using 75 percent cost and using safety benefits of "P" & "K" average

BEST DOCUMENT AVAILABLE

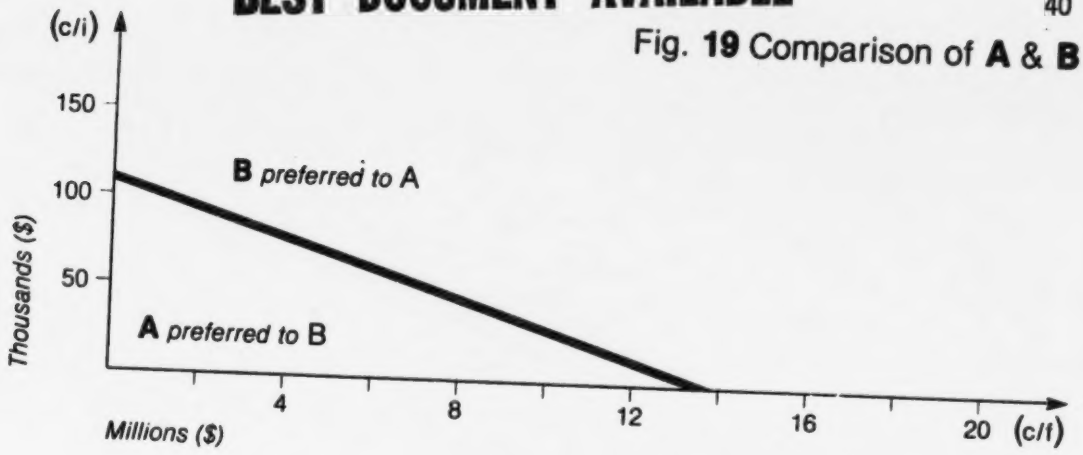


Fig. **19** Comparison of **A** & **B**

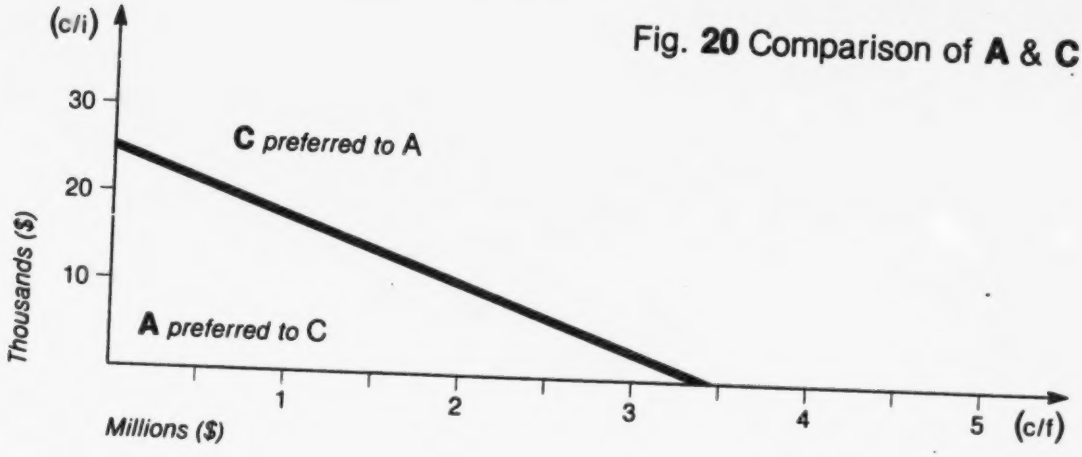


Fig. **20** Comparison of **A** & **C**

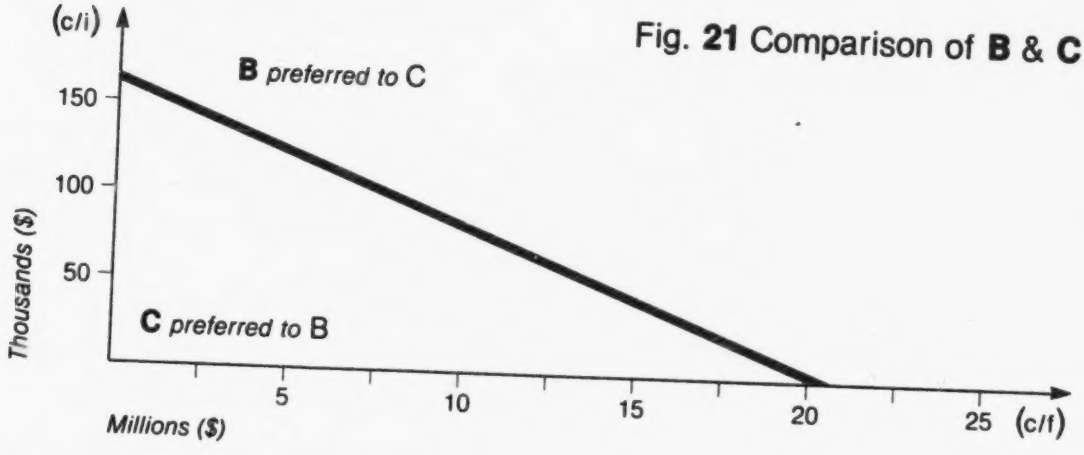


Fig. **21** Comparison of **B** & **C**

Figures 19-21 Comparisons of (A), (B), & (C) using 50 percent cost and using safety benefits of expert "K"

BEST DOCUMENT AVAILABLE

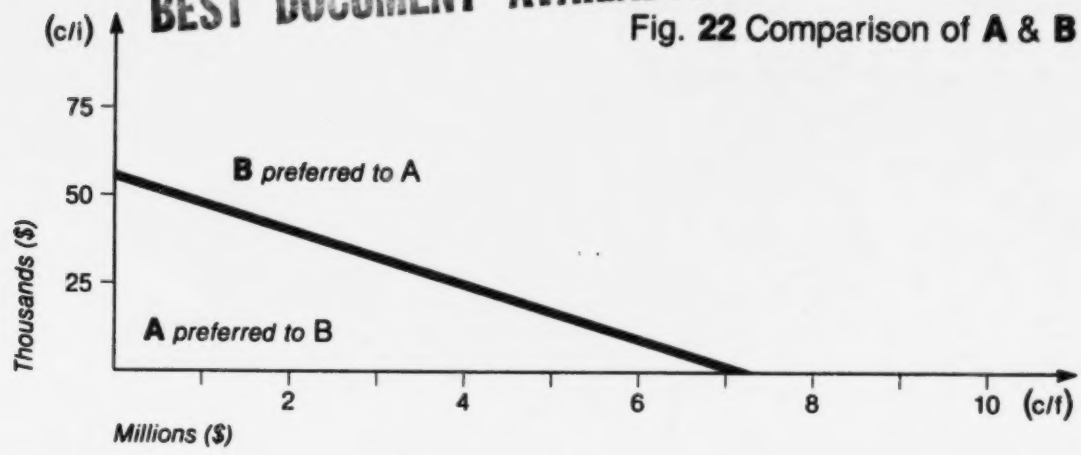


Fig. **22** Comparison of **A** & **B**

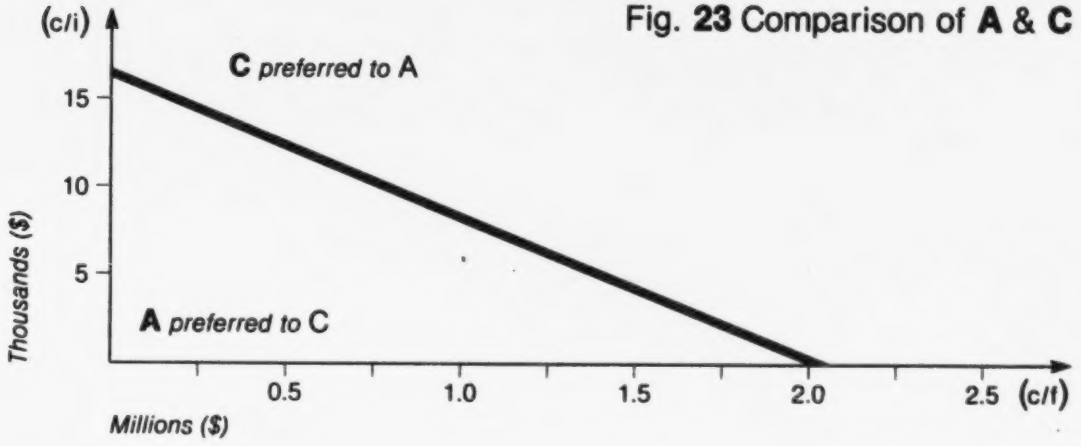


Fig. **23** Comparison of **A** & **C**

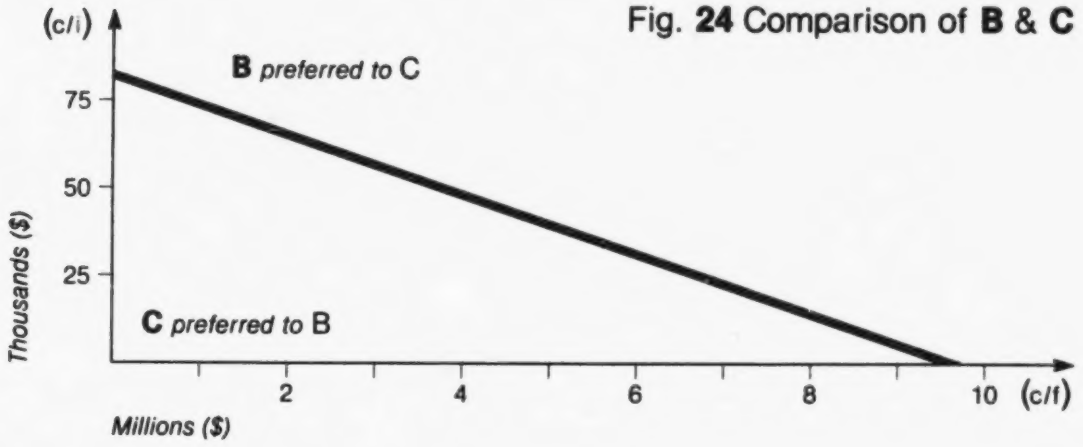


Fig. **24** Comparison of **B** & **C**

Figures 22-24 Comparisons of (A), (B), & (C) using 50 percent cost and using safety benefits of expert "P"

BEST DOCUMENT AVAILABLE

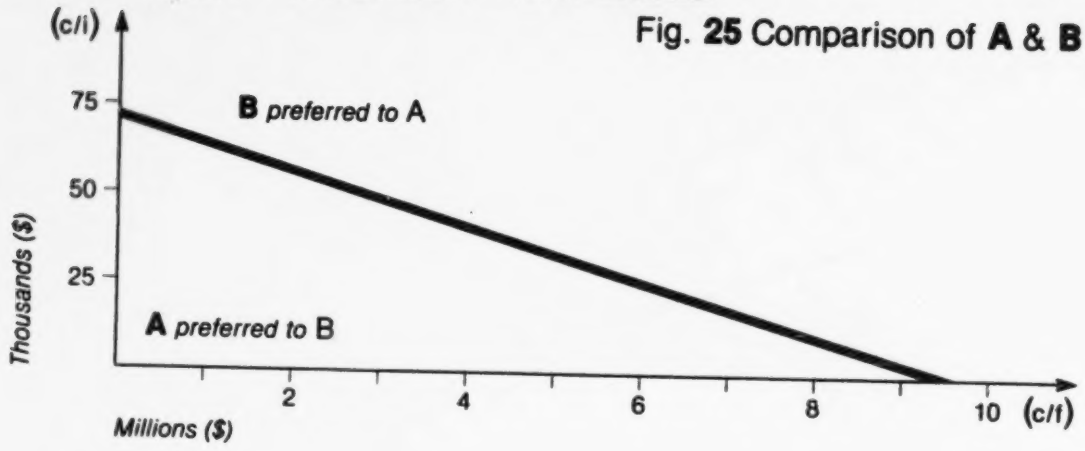


Fig. **25** Comparison of **A** & **B**

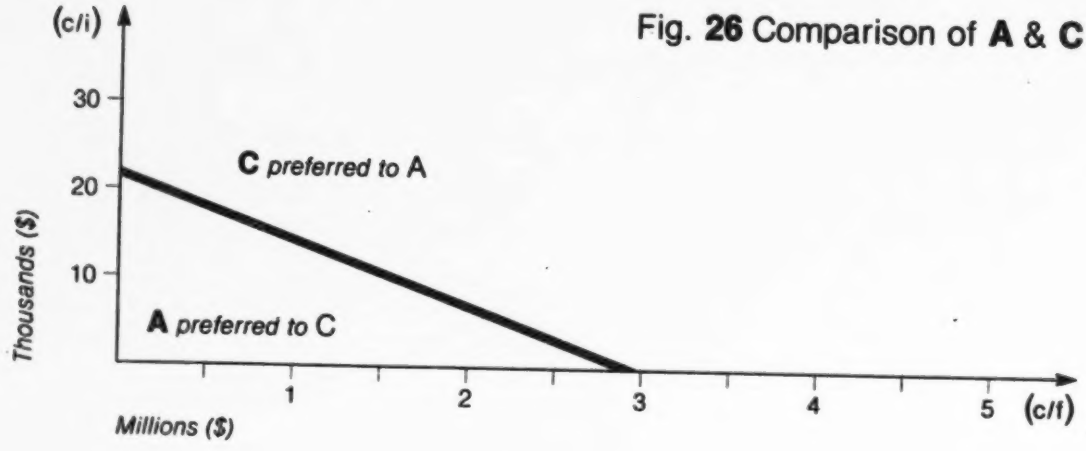


Fig. **26** Comparison of **A** & **C**

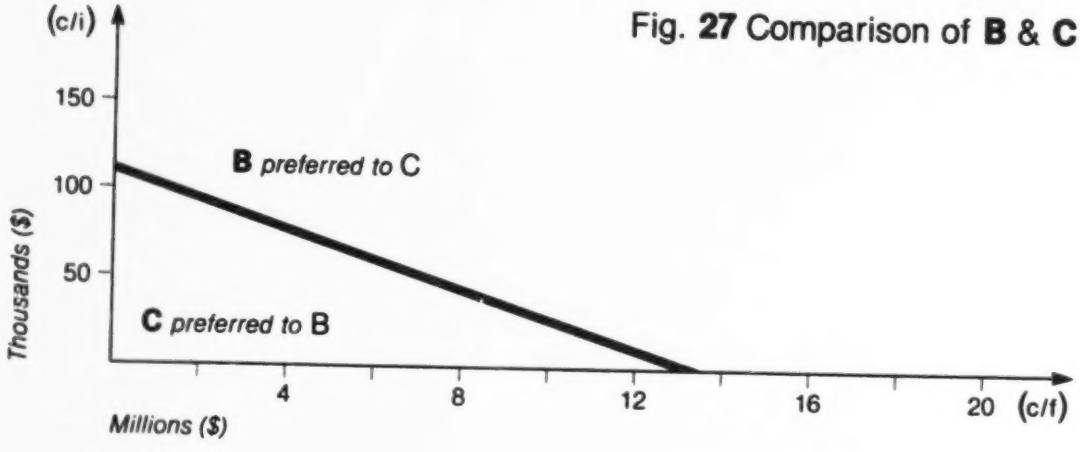


Fig. **27** Comparison of **B** & **C**

Figures 25-27 Comparisons of (A), (B), & (C) using 50 percent cost and using safety benefits of "P" & "K" average